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VIBRATING SYSTEM AND METHOD FOR USE IN SAND CONTROL AND FORMATION STIMULATION IN OIL AND GAS RECOVERY OPERATIONS

Background

[0001] This invention relates to a vibrating device for use in sand control and formation stimulation in an oil and gas recovery operation.

[0002] Many oil and gas downhole recovery operations, especially high-rate, high-permeability completions, produce reservoir fluids that contain fines, or formation sand. Therefore, support and screening devices, such as screens, slotted liners, and the like, have been utilized to support a gravel pack, or the like, in the well to stabilize the formation while permitting the recovered fluids to pass from the formation into the wellbore while preventing passage of fines or formation sand with the recovered fluids.

[0003] These support devices are often placed in a pressure-drop zone which subjects the devices to contamination from scaling (salt crystal growth) and other materials that are precipitated during production of the reservoir fluids. Thus, the devices must be cleaned either mechanically, which adds to the labor and cost of the project, or chemically, which may harm the metal parts of the devices.

[0004] Also, during the recovery operation from the wellbore, a "skin" develops around the wall of the wellbore which impedes the flow of fluid from the formation requiring stimulation techniques to remove the skin and stimulate the formation.

[0005] Therefore, what is needed is a device of the above type that simultaneously performs the above screening and stimulation functions yet eliminates the above problems.

Brief Description of the Drawings

[0006] Fig. 1 is a diagrammatic view of an embodiment of the sand control system of the present invention shown in a downhole environment.

[0007] Fig. 2 is a flow chart depicting steps of a method according to an alternate embodiment of the invention.

[0008] Fig. 3 is a graph depicting two variables in accordance with the embodiment of Fig. 2.

Detailed Description

[0009] Referring to Fig. 1 of the drawings, the reference 10 refers, in general, to a downhole tool installed in a wellbore 12. The tool 10 is connected to a wireline or coiled tubing 14, and is lowered to a depth in the wellbore 12 penetrating a producing formation F. It is also understood that a casing (not shown) can be provided in the wellbore 12 and that production tubing (not shown) is installed in the wellbore 12 above the tool 10.

[0010] Four axially-spaced, cylindrical gravel pack support and screening devices 16a-16d are mounted, in any conventional manner, to the wall of the wellbore 12 penetrating the formation F. The devices 16a-16d can be in the form of screens, slotted liners, or any similar type of gravel support device. Although not clear from the drawing due to scale limitations, it is understood that the devices 16a-16d define an annular space with the wall of the wellbore 12 that receives one or more gravel packs, or the like, (not shown). The purpose of each gravel pack is to improve the integrity of the wall of the wellbore 12, yet allow recovered fluids to pass to and through the devices 16a-16d and into the wellbore 12, while preventing the passage of any fines or sand from the fluids. Since these gravel packs are conventional, they will not be described in any further detail.

[0011] Two electrical drivers 18a and 18b are mounted on the tool 10 in an axially-spaced relation. The drivers 18a and 18b are conventional and, as such, are connected to a source of AC or DC power received from ground surface and are adapted to supply electrical power for reasons to be described.

[0012] An acoustic transducer 20a is mounted on the wall of the wellbore 12 between the devices 16a and 16b; an acoustic transducer 20b is mounted on the wall of the wellbore 12 between the devices 16b and 16c; and an acoustic transducer 20c is mounted on the wall of the wellbore 12 between the devices 16c and 16d.

[0013] The acoustic transducers 20a-20c can be in the form of conventional electromechanical transducers, or converters, such as tuning forks, cantilevers, oval-mode tools, magnetostrictive drivers, or piezoelectric transducers that vibrate in response to an input signal. Preferably, the acoustic transducers 20a-20c are driven, or excited by electrical power output from the drivers 18a and 18b and operate efficiently at a desired, predetermined frequency when actuated. For example, one of the drivers 18a and 18b, as well as one or two of the acoustic transducers 20a-20c, can operate at a relatively high frequency; while the other driver and the other acoustic transducer(s) can operate at a relatively low frequency.

[0014] As a particular example of the type of acoustic transducers 20a-20c that can be used, if the desired frequency is above 4 kHz, one or more of the acoustic transducers 20a-20c can be in the form of piezoelectric transducers, such as those marketed under the designation PZT-4 by the Edo Corporation of Salt Lake City, Utah. If it is desired to operate below 4 kHz, one or more of the acoustic transducers 20a-20c can be in the form of conventional magnetostrictive drivers. In either case, the frequency, or frequencies, of the electrical output of the drivers 18a and 18b are matched to the frequencies of the acoustic transducers 20a-20c, so that the acoustic transducers 20a-20c are driven at their resonant frequencies, and the devices 16a-16d are designed to resonate at these frequencies.

[0015] The acoustic transducers 20a-20c are mechanically coupled to the devices 16a-16d in a manner so that vibrations of the acoustic transducers 20a-20c are imparted to the devices 16a-16d. The acoustic transducers 20a-20c can be designed to form, with the devices 16a-16d, one assembly, or package, that is inserted as a unit in the wellbore 12 and mounted to the wellbore 12 in a conventional manner.

[0016] The devices 16a and 16b provide equal and opposite loads on the acoustic transducer 20a, so that the acoustic transducer 20a can be used to vibrate the two devices 16a and 16b simultaneously. Similarly, the devices 16b and 16c provide equal

and opposite loads on the acoustic transducer 20b so that the acoustic transducer 20b can be used to vibrate the two devices 16b and 16c simultaneously; and the devices 16c and 16d provide equal and opposite loads on the acoustic transducer 20c so that the acoustic transducer 20c can be used to vibrate the two devices 16c and 16d simultaneously.

[0017] A pressure sensor 22a is mounted to the outer surface of the device 16b; a pressure sensor 22b is mounted between the outer surfaces of the devices 16c and 16d; and two pressure sensors 22c and 22d are mounted to the inner surfaces of the devices 16a and 16c, respectively. The pressure sensors 22a and 22b are adapted to sense the pressure of production fluid outside the devices 16a-16d, and the pressure sensors 22c and 22d are adapted to sense the pressure of the fluid inside the devices 16a-16d. Thus, the pressure sensors 22a-22d can be said to sense a condition of the devices 16a-16d.

[0018] A control unit 24, which can be in the form of a microprocessor, or the like, is mounted to the wall of the wellbore 12 just above the device 16a and, although not shown in the drawing in the interest of clarity, is electrically connected to the pressure sensors 22a-22d. The control unit 24 is adapted to process signals from the pressure sensors 22a-22d and generate a corresponding output signal, for reasons to be described.

[0019] A telemetry device 26 is mounted on the tool 10 and is adapted to collect data from the control unit 24 and transmit the data to the ground surface for processing. Since the telemetry device 26 is conventional it will not be described in detail.

[0020] A conductor assembly 28, shown by a dashed line, extends from the drivers 18a and 18b, the telemetry device 26, through the wireline or coiled tubing 14 and to ground surface; and a conductor assembly 28a extends from the control unit 24 to the conductor assembly 28. It is understood that the conductor assemblies 28 and 28a include sufficient cables to transmit electrical power and telemetry between the ground surface and the drivers 18a and 18b, the control unit 24, and the telemetry device 26. In the latter context, it is understood that the telemetry can include depth, pressure, and temperature data, and any other necessary wellbore data. Although not shown in the

drawings in the interest of clarity, it is understood that the pressure sensors 22a-22d can also be electrically connected to the conductor assembly 28 for the same reasons.

[0021] In operation, the devices 16a-16d and the acoustic transducers 20a-20c are inserted in, and mounted to, the wellbore 12, preferably as a package, adjacent the formation F as shown in Fig. 1, and the devices 16a-16d are packed with sand, or the like, to form a gravel pack. Production is started and, as a result, fluids recovered from the formation F pass through the gravel packs and the devices 16a-16d and upwardly in the wellbore 12 to the above-mentioned production tubing (not shown) for passing to the ground surface, while the devices 16a-16d prevent fines or sand from the fluids from passing with the fluids.

[0022] The pressure sensors 22a and 22b sense the pressure of the recovered fluid outside the devices 16a-16d and generate corresponding signals which are transmitted to the control unit 24. Similarly, the pressure sensors 22c and 22d sense the pressure of the recovered fluid inside the devices 16a-16d and generate corresponding signals which are also transmitted to the control unit 24. The control unit 24 processes the above signals and is programmed to respond when the fluid pressure outside the devices 16a-16d exceeds the fluid pressure inside the devices 16a-16d by a predetermined amount, indicating that the devices 16a-16d are at least partially clogged with scale, and/or any other foreign materials. When this happens, the control unit 24 sends a corresponding signal to the telemetry device 26 which, in turn, sends a corresponding signal, via the conductor assembly 28, to the ground surface.

[0023] The operator at the ground surface responds to the above signal from the telemetry device 26, and lowers the tool 10, via the wireline or coiled tubing 14, to a position in which the drivers 18a and 18b are approximately aligned with the acoustic transducer 20a as shown in Fig. 1. The drivers 18a and 18b are activated by the electrical power from the ground surface, which is transmitted to the drivers by the conductor assembly 28. The drivers 18a and 18b preferably convert the frequency of the electrical power to drive the acoustic transducer 20a to cause corresponding vibration of the devices 16a and 16b at their resonant frequency in the manner discussed above. These vibrations dislodge, fracture, or break up, the scale, and/or any other foreign materials, accumulating on the devices 16a and 16b. These vibrations can

also mobilize fines inside the gravel packs and fines located in the wellbore 12 and in the formation F near the wellbore 12. The scale, fines, and/or materials recovered from the devices 16a and 16b are allowed to fall to the bottom of the wellbore 12, or could be circulated in any conventional manner to the ground surface for recovery. The circulation can occur with non-production fluids in a well intervention mode. However, this method is especially useful in that the scale, fines, and/or materials can be produced to the ground surface together with production fluids. Consequently, there is no lost production using this intervention mode.

[0024] The audio output from the acoustic transducer 20a, which can be in the range of 4,000-30,000 Hz, also stimulates the formation F adjacent the devices 16a and 16b and reduces the "skin" around the wellbore 12 that can slow the flow of production fluid from the formation to the wellbore 12.

[0025] The tool 10 is then lowered further to a position in which the drivers 18a and 18b are approximately aligned with the acoustic transducer 20b and the above method is repeated in connection with the devices 16b and 16c, after which the method is repeated again with the acoustic transducer 20c to vibrate the devices 16c and 16d.

[0026] As a result of all of the foregoing, scale, and/or any other foreign materials accumulating on the devices 16a-16d, are broken up without causing any physical or chemical damage to the devices 16a-16d, while the formation F is stimulated and the skin around the wellbore 12 is reduced.

[0027] According to another embodiment of the invention as shown in Fig. 2, the pressure sensors 22a-22d are eliminated and a reservoir model can be utilized to provide information relating to the need to vibrate the devices 16a-16d in the above manner. Otherwise the embodiment of Fig. 2 contains the same components as the embodiment of Fig. 1. According to the embodiment of Fig. 2, data is initially collected to generate an initial reservoir model which is inputted to the control unit 24. After production of fluid from the formation F is initiated, the production information is generated and inputted to the control unit 24 which matches the information to the initial model and adjusts the model as necessary to set a working model. As production continues, the additional production data is collected and inputted to the control unit 24 which compares the data to the working model. If there is a match, the data is fed back

to the control unit 24 for further processing; and, if there is no match, the drivers 18a and 18b are actuated to drive the acoustic transducers 20a-20c and thus initiate the device vibration/production stimulation cycle as described above.

[0028] Fig. 3 is a graph of the simulated production from the wellbore 12 vs. time and shows the reservoir model of Fig. 2 by the rectangular data points, and a deviation from the model by the triangular data points, both before and after the scale is removed from the devices 16a-16d and the formation F is stimulated, including removal of the skin, in accordance with the foregoing "treatment". It is noted that the treatment brings the production back to the model values.

[0029] Thus, the system and method of the present invention performs the screening and stimulation functions yet eliminates the problems discussed above.

[0030] Several variations may be made in both of the above embodiments without departing from the scope of the invention. These variations are as follows:

[0031] (1) Rather than having an operator at the ground surface activate the drivers 18a and 18b in response to a corresponding signal received from the control unit 24, as discussed above, a control unit, such as another microprocessor, the control unit 24, or other similar device, could be provided to perform this function.

[0032] (2) Rather than use the reservoir model discussed in connection with Fig. 2 instead of the pressure sensors 22a-22d, the reservoir model could be used in addition to the pressure sensors 22a-22d.

[0033] (3) The tool 10 could be lowered into the wellbore 12 prior to the initiation of the fluid recovery process or at least prior to the sensing of the presence of scale, and any other foreign materials, as discussed above.

[0034] (4) The control unit 24 can be programmed to adjust the pressure differential required to actuate the drivers 18a and 18b.

[0035] (5) The number and type of screening devices 16a-16d, drivers 18a and 18b, acoustic transducers 20a-20c, and/or pressure sensors 22a-22d can be varied. Although two drivers 18a and 18b have been shown driving the acoustic transducers 20a-20c, a single driver can be used. Placing multiple drivers on the tool 10 can allow multiple acoustic transducers to be driven simultaneously.